

METHOD OF AND INSTRUMENT FOR ANALYZING A GAS

RELATED PATENT APPLICATIONS & INCORPORATION BY REFERENCE

This application is a continuation application of U. S. Serial No. 10/106,635, entitled "Method Of And Instrument for Analyzing A Gas," filed March 26, 2002, now U. S. Patent No. _____. This related application is incorporated herein by reference and made a part of this application. Moreover, the inventors incorporate herein by reference any and all U. S. patents, U. S. patent applications, and other documents cited or referred to in this application or cited or referred to in the U. S. patents and U. S. patent applications incorporated herein by reference.

BACKGROUND OF INVENTION

It is common practice to analyze gases to determine the quantitative level of certain constituents (herein analytes) of the gas. Frequently, gases are analyzed for their oxygen content, particularly methane from coal or gas wells. The higher levels of oxygen in methane gas lead to corrosion of pipe lines and also may present a danger of explosion. When oxygen levels exceed, for example, 20 parts per million (ppm), an alarm or signal is given which is used to shut down the flow of methane from a well being monitored.

The instrument used to perform such analysis typically includes an assembly of discrete components including valves, valve fittings, flow meters, scrubbers, pressure regulators, needle valves, etc. Because of the numerous components, these instruments are very bulky, taking up space which could be utilized for better purposes. Most, if not all,

1 of these discrete components are connected by tubing. The
2 connections are prone to leak, particularly if they have to be broken
3 and remade. Typically, the scrubber employed contains a material that
4 removes deleterious constituents from the sample gas. This scrubber
5 material changes color when exhausted and consequently needs to be
6 replaced frequently, requiring disconnection of at least some of the
7 components.

8 9 SUMMARY OF INVENTION

10
11 This invention has several features. Without limiting the scope of
12 this invention as expressed by the claims that follow, its more
13 prominent features will now be discussed briefly. After considering
14 this discussion, and particularly after reading the section entitled,
15 "DETAILED DESCRIPTION," one will understand how the features of this
16 invention provide its benefits, which include, but are not limited to,
17 compactness, ease of assembly of components, ease of replacement of
18 components when required, minimization of disconnection of
19 components, and avoidance of leakage from or into the instrument.

20 The first feature of the gas analyzer instrument of this invention
21 is that it includes a block having a sample gas inlet, a calibration gas
22 inlet, and a gas outlet. Typically, the block has a height of from 3 to 4
23 inches, a width of from 3 to 4 inches, and a depth of from 1 to 3
24 inches. A valve and a detection cell are mounted to the block, with the
25 cell being mounted in a manner that allows the gas being analyzed to
26 flow past it. Typically, the detection cell is seated within a cavity in the
27 block. The valve has a closed position, a sample gas position, and a
28 calibration gas position. With the valve in the closed position or the
29 calibration gas position, essentially all of the sample gas exits the gas

1 outlet. With the valve in the sample position, a portion of the sample
2 gas flows past the detection cell. The block includes (1) a first
3 passageway extending from the calibration gas inlet through the valve
4 and past the detection cell to the gas outlet, (2) a second passageway
5 extending from the sample gas inlet through the valve and past the
6 detection cell to the gas outlet, and (3) a third passageway that is in
7 communication with the gas outlet.

8 The second feature is the use of a sample gas orifice and a bypass
9 orifice. A calibration gas orifice may also be employed. The sizes of
10 these orifices may vary, and in some instances within the same
11 instrument, they have different sizes depending upon the application
12 and environment under which the instrument is being used. The
13 sample gas orifice is along the second passageway upstream of the
14 valve, and the bypass orifice is along the third passageway downstream
15 of the sample gas orifice. As sample gas is being introduced through
16 the sample gas inlet when the valve is in the sample gas position, at
17 least a portion of the sample gas flows through the third passageway
18 and exits the gas outlet. The size of the orifices is important for
19 controlling the flow rate of gas through the instrument within a
20 selected flow rate range over a variable gas inlet pressure over a given
21 range. In a preferred embodiment of this invention, the gas introduced
22 through either the sample gas inlet or the calibration gas inlet is within
23 the range from 1 to 100 pounds per square inch gage (psig), and the
24 orifices are sized so that the flow rate of gas through the instrument is
25 within a predetermined range from 0.5 to 7 standard cubic feet per
26 hour. Under these parameters, the orifices have an area from 0.00001
27 to 0.0005 square inch. When these orifices are substantially circular,
28 they have a diameter from 0.004 to 0.022 inch.

29 In a preferred embodiment, the sample gas orifice is always in

1 communication with the gas outlet through the bypass orifice
2 regardless of the position of the valve. Consequently, at least a portion
3 of the sample gas always exits the gas outlet as long as sample gas flows
4 into the sample gas inlet. In one preferred embodiment of this
5 invention, the instrument is designed so that most of the gas entering
6 the instrument flows past the detection cell. This is not, however,
7 critical. In some cases, particularly where it is desired to minimize the
8 lag time between sampling a gas stream and testing of the sampled gas,
9 most of the sample gas entering the instrument flows through the
10 bypass orifice and out the gas outlet, and only a minor portion flows
11 past the detection cell. In another case where it is desired to minimize
12 the amount of sample gas being tested, most of the sample gas flows
13 past the detection cell. In this case, the bypass orifice has a
14 predetermined size that is substantially greater than the
15 predetermined size of the sample gas orifice, preferably, the area of the
16 bypass orifice is at least two times greater than the area of the sample
17 gas orifice.

18 The third feature is that a scrubber is attached to the block
19 upstream of the detection cell and down stream of the sample gas
20 orifice. The scrubber removes from the sample gas unwanted
21 substances, particularly those that have a deleterious effect on the cell.
22 The scrubber comprises a see-through container made of either a
23 transparent or translucent material. This see-through container holds
24 scrubber material that removes the unwanted substances and changes
25 color to indicate that the scrubber material is exhausted and needs
26 replacement. The container is mounted to be detached from the block
27 to provide access to the scrubber material to replace exhausted
28 material. Preferably, there is a filter between the valve and the
29 scrubber. The sample gas orifice and bypass orifice are also sized to

1 maintain the pressure within the scrubber when the valve is in the
2 closed position or the calibration gas position at a reduced pressure
3 substantially below the elevated inlet pressure of the gas being
4 analyzed, preventing a build up of excessive pressure in the scrubber
5 when the valve is in either the closed position or the calibration gas
6 position.

7 The fourth feature is that, in a preferred embodiment of this
8 invention, gas leaves the block and then subsequently re-enters the
9 block. In this embodiment, the second passageway has a first branch
10 extending from the sample gas orifice through the block to a first outlet
11 and a second branch extending from a first inlet through the valve and
12 the detection cell to the gas outlet. The scrubber is connected between
13 the first outlet and the first inlet to enable the sample gas to flow
14 through the scrubber prior to flowing through the valve and past the
15 detection cell. The sample gas orifice is along the first branch of the
16 second passageway upstream of the first outlet. The bypass orifice is
17 also upstream of the first outlet.

18 The fifth feature is that the instrument includes multiple flow
19 paths. The calibration gas orifice is in communication with the gas
20 outlet through a first flow path including the valve and the detection
21 cell, and the sample gas orifice is in communication with the gas outlet
22 through a second flow path including the scrubber, the valve, and the
23 detection cell. The sample gas orifice is along the second flow path,
24 and the bypass orifice is positioned between the sample gas orifice and
25 the gas outlet, allowing a portion of the sample gas to exit the gas
26 outlet. The first flow path and second flow path each includes a
27 common flow path downstream of the detection cell. This common
28 flow path has a first branch that extends through the block between
29 the detection cell and an entrance port of a flow meter and a second

1 branch between an exit port of the flow meter and the gas outlet. The
2 second flow path includes a third branch that extends through the
3 block from the sample gas inlet through the sample gas orifice to an
4 entrance port of the scrubber and a fourth branch that extends
5 through the block from an exit port of the scrubber to the valve.

6 The sixth feature is that the valve has a unique structure. It
7 includes a cylindrical rotary member mounted within a cylindrical
8 cavity in the block to rotate between the closed position, the sample
9 gas position, and the calibration gas position. The rotary member has
10 a side wall terminating at an inner face surface and a gas conduit
11 extending between the rotary member's inner face surface and the
12 rotary member's side wall. The inner face surface is perpendicular to
13 the longitudinal axis of the cylindrical rotary member. The gas conduit
14 terminates at one end in a first opening on the rotary member's inner
15 face surface and at another end in a second opening on the rotary
16 member's side wall. The cavity has a side wall terminating at a sunken
17 face surface, and this sunken face surface has therein a first aperture in
18 communication with the detection cell through the first passageway.
19 There is a second aperture in the sunken face surface in
20 communication with the scrubber through the second passageway, and
21 a third aperture in communication with the calibration gas orifice
22 through the third passageway. When in the sample gas position, the
23 rotary member's inner face surface covers the third aperture to
24 prevent communication between the calibration gas orifice and the
25 detection cell. When in the calibration gas position, the rotary
26 member's inner face surface covers the second aperture to prevent
27 communication between the scrubber and the detection cell. When in
28 the closed position, the rotary member's inner face surface covers both
29 the second aperture and the third aperture to prevent any gas from

1 flowing past the detection cell. There are seal members surrounding
2 the second and third apertures that bear against the inner face surface
3 of the rotary member.

4 Other features include the use of a flow meter and a heater. The
5 flow meter is mounted to an exterior surface of the block and is
6 downstream of the detection cell. It has an exit port in communication
7 with the gas outlet through a fourth passageway in the block that by-
8 passes the detection cell. The flow meter is in communication with the
9 sample gas orifice, the calibration gas orifice, and the gas outlet in a
10 manner that allows gas to flow through the flow meter prior to exiting
11 the block through the gas outlet. The heater is mounted to the block,
12 preferably within a cavity. A thermistor, connected in a control circuit
13 for the instrument and mounted to the block next to the heater,
14 compensates for the variation in cell output with temperature.

15 This invention also includes a method of measuring the amount
16 of analyte in a sample gas. This method includes the steps of

17 (a) passing the sample gas by a detection cell mounted in a block
18 having a plurality of passageways therein that direct the flow of gas
19 between a gas inlet and a gas outlet,

20 (b) passing a calibration gas by the detection cell for calibration
21 of said cell, said calibration gas flowing at least in part through a
22 different passageway than the sample gas,

23 (c) controlling which passageway gas flows through by a valve
24 mounted in the block and moveable between a first position when the
25 calibration gas is to flow between the gas inlet and gas outlet and a
26 second position when the sample gas is to flow between the gas inlet
27 and gas outlet, and

28 (d) providing in the block a sample gas orifice along one
29 passageway, and a bypass orifice in the block along another

1 passageway positioned between the sample gas orifice and the gas
2 outlet that allows a portion of the sample gas to exit the gas outlet
3 when the valve is in the first position, said orifices being sized so that,
4 with gas entering the instrument at an inlet orifice pressure within a
5 predetermined range, the flow rate of gas through the instrument is
6 within a predetermined range.

7 8 DESCRIPTION OF DRAWINGS 9

10 A preferred embodiment of this invention, illustrating all its
11 features, will now be discussed in detail. This embodiment depicts the
12 novel and non-obvious gas analyzing instrument and method of this
13 invention as shown in the accompanying drawings, which are for
14 illustrative purposes only. These drawings includes the following
15 figures (Figs.), with like numerals indicating like parts:

16 Fig. 1 is a front elevational view of the gas analyzer instrument of
17 this invention.

18 Fig. 2 is a schematic diagram of the gas analyzer instrument
19 shown in Fig. 1.

20 Fig. 3 is a perspective of the block used in the gas analyzer of this
21 invention having a scrubber and a flow meter attached to the block.

22 Fig. 4 is an exploded perspective view of the block, scrubber, and
23 flow meter shown in Fig. 3.

24 Fig. 5 is perspective view of the block shown in Fig. 3 looking at
25 the side of the block having the calibration gas orifice, sample gas
26 orifice, and gas outlet.

27 Fig. 6 is a cross-sectional view of the block taken along line 6-6 of
28 Fig. 3.

29 Fig. 7 is a schematic diagram showing the flow path of the

1 calibration gas into the instrument of this invention and to the
2 detection cell.

3 Fig. 8 is a schematic diagram showing the flow path of the sample
4 gas into the instrument of this invention, through the scrubber and to
5 the detection cell.

6 Fig. 9 is schematic diagram showing the common flow path of the
7 calibration gas and sample gas as they as they flow past the detection
8 cell, through the flow meter, and exit the instrument of this invention
9 through the gas outlet.

10 Fig. 10 is a perspective view similar to that shown in Fig. 3
11 depicting in dotted lines various internal components of the
12 instrument of this invention.

13 Fig. 11 is a front elevational view of the block with attached
14 scrubber and flow meter depicting in dotted lines various internal
15 components of the instrument of this invention.

16 Fig. 12 is a sectional view taken along line 12-12 of Fig. 6 showing
17 the sunken face surface of the cavity in the block in which the valve
18 rotor is seated.

19 Fig. 13 is a sectional view taken along line 13-13 of Fig. 4 showing
20 the valve rotor's inner face surface.

21 Fig. 14 is a sectional view taken along line 14-14 of Fig. 12.

22 Fig. 15 is a sectional view taken along line 15-15 of Fig. 12.

23 Fig. 16 is a top plan view, with sections broken away, of the block
24 used in the instrument of this invention.

25 Fig. 17 is a graph showing the relationship of the inlet pressure
26 and downstream pressure in the scrubber.

DETAILED DESCRIPTION

As shown best in Figs. 1 and 2, the instrument 10 of this invention includes a case 12 enclosing a control circuit 14 for the instrument and a block 18 made of metal such as, for example, nickel plated aluminum. Preferably, the block is drilled to create the inlets, outlets, cavities and passageways needed as discussed subsequently in detail, and any unnecessary openings are filled with gas-tight stoppers. A more expensive technique, would employ a casting technique to form the inlets, outlets, cavities and passageways needed.

Mounted to the block 18 (Fig. 2) are a scrubber 9, a flow meter 11 (Fig. 2), a detection cell 30 (Fig. 2), and a valve 40. The control circuit 14 includes a liquid crystal display 16 and buttons 14a through 14e on the front 12c of the case 12. Mounted on a side 12a of the case 12 is an external power supply 20 for the control circuit 14. The buttons 14a through 14e enable a user to set the range over which the instrument 10 measures an analyte in a gas sample (GS), as well as allowing calibration and alarm setting. The user may inspect the instrument settings by pressing the relevant buttons 14a through 14e, whereas to alter the settings, the user must first press both buttons 14a and 14b simultaneously, and then whichever of the buttons 14a through 14e needed to accomplish the desired change. There are potentiometers (not shown) in the control circuit 14 associated with each of the buttons 14c through 14e that each have a manually adjustable set screw 14c', 14d', and 14e' respectively for setting the value of each individual potentiometer. These potentiometers have no effect on the instrument operation unless both the buttons 14a and 14b have been simultaneously pressed, and then only when buttons 14c, 14d or 14e are pressed will its associated potentiometer be effective.

1 The amount of analyte in a gas is shown in engineering units, such as
2 ppm, on the display 16 no matter which range has been selected,
3 although the output voltage may no longer represent the sample
4 concentration if it is outside the value of the selected output range. If
5 the amount of analyte is outside the selected range, the user simply
6 changes the range by manipulation of the buttons 14a and 14 b.

7 The instrument 10 is first calibrated using a calibration gas,
8 commonly referred to as "SPAN" gas. For example, when the
9 instrument 10 is used to analyze a sample gas to determine the amount
10 of oxygen (the analyte) in such sample gas, a calibration gas (CG) is
11 used having therein a known oxygen concentration. By manipulation
12 of the buttons 14a through 14e and adjusting the appropriate set screw
13 14e', the user sets the readout on the display 16 to correspond to the
14 known concentration of oxygen in the calibration gas introduced into
15 the instrument 10 through a SPAN gas inlet 5 including a calibration
16 gas orifice 3. Subsequent to such calibration, a sample gas (SG)
17 containing an unknown amount of oxygen is introduced into the
18 instrument 10 through a sample gas inlet 6. Both the calibration gas
19 and the sample gas exit the instrument 10 through a gas outlet 7. A
20 coalescing filter 8 filters the sample gas prior to entry into the
21 instrument 10 and removes any condensed moisture and particulates
22 in the sample gas.

23 The block 18 enables the instrument 10 to avoid using tubing
24 typically employed in conventional analytical instrumentation. As best
25 shown in Figs. 3 through 9, the block 18 has a generally L-shaped
26 configuration formed by machining a metal cube to provide a corner C
27 between a pair of legs L1 and L2. The block 18 has a topside 18a,
28 bottom side 18b, front side 18c, back side 18d, right side 18e and left
29 side 18f. The block 18 is machined to create gas passageways 22a, 22b,

22b', 22c, 22c', 22d, 22d' and 23 through the block 18 and provide cavities 24, 26, and 28 (Figs. 4 and 6) within the block having open cylindrical entryways 24a, 26a and 28a, respectively. The cavities 24 and 26 both have their respective entryways 24a and 26a in the front side 18c of the block 18 and the cavity 26 is conveniently located directly beneath the cavity 24. The entryway 28a is in the bottom side 18b of the block 18.

As illustrated in Figs. 1 and 4, the lower portion of the scrubber 9 extends outward from the bottom 12b of the case 12. This scrubber 9 includes an internal hollow tube 72 that has an upper threaded end 72a screwed into a threaded receptacle 73 (Figs. 10 and 11) in the block 18. The tube 72 is enclosed in a transparent cylindrical pipe 74 and its is concentrically positioned relative to this pipe. Contained within the space S between the tube 72 and pipe 74 is a suitable scrubbing material M used to remove unwanted substances from the sample gas. There is an end cap 76 sealing an open lower end 74a of the pipe 74. The inside surface 76a of the end cap 76 has a central threaded receptacle 76b into which is screwed a lower threaded end 72b of the tube 72. The outside diameter of the pipe 74 is about equal to the diameter of the entryway 28a. Lodged in an annular groove 75 in the face of the entryway 28a is an o-ring 80 that seals the interface between the upper end of the pipe 74 and the entryway 28a. The passageway 22b terminates in the cavity 28 immediately above the space S between the pipe 74 and tube 72, so the sample gas upon entering the scrubber 9 immediately contacts the scrubbing material M. Near the lower end 72b of the tube 72 is a hole 78 through which sample gas flows after first flowing through the scrubbing material M that removes the unwanted substances from the sample gas as the gas flows through the instrument 10.

1 A typical unwanted substance is, for example, hydrogen sulfide, a
2 deleterious contaminant frequently present in methane gas being
3 analyzed. A suitable scrubber material for hydrogen sulfide is sold
4 under the name Purafil obtained from The Purafil Corporation. This
5 scrubbing material M changes color as it absorbs hydrogen sulfide gas,
6 gradually changing from its initial bright purple to a gray-brown that
7 indicates that the scrubbing material needs to be removed and
8 replaced. This is accomplished simply by grasping the exterior of the
9 pipe 74 and rotating the entire scrubber assembly to unscrew the
10 upper threaded end 72a of the tube 72 from the threaded receptacle
11 73. The used scrubbing material is discarded and replaced with fresh
12 material, and the threaded end 72a is screwed back into the threaded
13 receptacle 73 to re-attached the scrubber 9 to the block 18.

14 Any deleterious substances should be removed from the sample
15 gas prior to the gas flowing into the detection cell 30. This cell 30
16 generates on contact with gas an electrical signal indicating the amount
17 of analyte present in the gas. A suitable detection cell 30 is sold by
18 Advanced Micro Instruments, Inc. under the designation T-2. The
19 detection cell 30 is seated in the cavity 24, and electrical leads 38
20 extending through an insulator member 38a seated in the topside 18a
21 of the block 18 connect the cell to the control circuit 14. The entryway
22 24a to the cavity 24 is threaded and a threaded cylindrical cover 32 is
23 screwed into this entryway 24a, which is about the same diameter as
24 the cover 32. An o-ring 34, near the bottom of the entryway 24a and
25 the inside of the cover 32, seals the cavity 24 to prevent gas from
26 escaping through the interface between the cover 32 and the entryway
27 24a. A preferred way of mounting the cell 30 is disclosed in U. S. Patent
28 No. 5,728,289.

1 The flow meter 11 is attached by screws (not shown) to the
2 exterior of the block 18, fitting into the corner C. A port P1 in the
3 block 18 is aligned with an inlet 11b (Figs. 2 and 10) in the flow meter
4 11, and another port P2 in the block 18 is aligned with an outlet 11c in
5 the flow meter 11. There is a channel 13 (Fig. 10) extending between
6 the inlet 11b and outlet 11c. The port P2 is at one end of the
7 passageway 22c'. The other end of the passageway 22c' terminates at
8 the gas outlet 7. O-rings 15 provide seals at the interfaces between the
9 ports P1 and P2 and the inlets 11b and outlet 11c. As depicted in Fig. 1,
10 there is a window 12c in the case 12 enabling the user to observe the
11 flow meter's scale 11a that indicates the flow rate of gas (either sample
12 gas or calibration gas) as it flows through the instrument 10.

13 Optionally, the instrument 10 may employ a heater 44. The
14 heater 44 may be desired because it is important that water and other
15 vapors present in the sample gas are not allowed to condense within
16 the block 18 and particularly on the cell 30, affecting its performance
17 negatively. There is a heater pocket 42 (Fig. 10) having an opening
18 42a in the left side 18e in the block 18 that enables the heater 44 (Fig.
19 4) to be positioned therein. A C-ring 46 (Fig. 4) snaps into the opening
20 42a to retain the heater 44 within the pocket 42. There is thermistor
21 48 (Fig. 2) lodged within the block 18 adjacent the heater 44. This
22 thermistor 48 is a component of the control circuit 14. It functions to
23 senses temperature, allowing other electronic devices (not shown) of
24 the control circuit 14 to adjust to compensate for variations in output
25 of the cell 30 with temperature. The control circuit 14 is designed in
26 accordance with well known electronic engineering principles.

27 The position of the valve 40 establishes the flow path of gas
28 through the instrument 10. The valve 40 has a control knob 40a
29 projecting from the front 12c of the case 12 that the user employs to

1 select one of three valve positions: a calibration gas position CG, a
2 sample gas position SG, and an OFF position. As best illustrated in Figs.
3 3, 4, 6, and 12 through 15, the valve 40 includes a cylindrical rotor 50
4 seated within the cavity 26. A rotor stem 50a projects outward from an
5 exterior side (not shown) of the rotor 50 through a disk shaped valve
6 retainer plate 52 seated in the entryway 26a, and four screws 54 secure
7 the retainer plate to the block 18. The valve retainer plate 52 holds the
8 rotor 50 in position within the cavity 26, but allows the rotor to be
9 rotated either clockwise or counter clockwise to move it into one of
10 three different valve positions mentioned above. The rotor 50 is
11 preferably made of aluminum, anodized and sealed. A detent
12 mechanism (not shown) including ball detent (not shown) with a
13 detent spring (not shown) may optionally be used to provide a tactile
14 sensation as the user moves the valve 40 into one of the three different
15 positions. The movement of the ball into one of the position, CS, SG or
16 OFF, indicates that the valve 40 is either in the calibration position,
17 sample position, or closed position.

18 A bottom side 50c of the rotor 50 presses snugly against a
19 substantially flat, sunken bottom wall 26c of the cavity 26. A Buna-n o-
20 ring 56, positioned in an annular groove 58 in the side wall 50d of the
21 rotor 50, provides a seal so that gas cannot escape via the interface
22 between the valve rotor 50 and the cavity entryway 26a. The valve
23 knob 40a is fitted on the stem 50a after the valve retainer plate 52 is
24 attached to the block 18. A gas conduit 64 extends between the bottom
25 side 50c and the side wall 50d of the rotor 50 wall, terminating at one
26 end in an opening 64a on the bottom side 50c and at another end in an
27 opening 64b on side wall 50d.

28 There are three of spaced apertures 60, 61 and 62 in the bottom
29 wall 26c of the cavity 26. The aperture 60 is in communication with the

1 detection cell 30 through the passageway 23. The aperture 61 is in
2 communication with the scrubber 9 through the passageway 22b'. One
3 end of the passageway 22b' terminates at the aperture 61 and the
4 other end of this passageway terminates at a filter 82 (Fig. 2). This
5 filter 82 is made of sintered metal and is within the upper threaded
6 end 72a of the tube 72. There is a narrow section of tube 72 next to the
7 thread end 72a containing an o-ring (not shown) that effectively seals
8 the passageway 22b' from the cavity 28 so the gas flows from the tube
9 72 into the passageway 22b' without leakage. The aperture 62 is in
10 communication with the calibration gas orifice 5 through the
11 passageway 22a, which terminates at the aperture 62.

12 As shown in Figs. 12, 14, and 15, a recess 66 surrounds each of
13 the apertures 61 and 60. Lodged in each of these recesses 66 is an
14 outer o-ring 68 having a Teflon® washer 70 concentrically seated
15 within the o-ring. An outer wall 70a of the washer 70 tapers inward so
16 that a wider end portion 70b of this washer is pressing against the
17 rotor's bottom side 50c and a narrower end portion 70c fits snug
18 within the o-ring 68. The truncated conical shape of the washers 70
19 keep the o-rings 68 from being rolled by friction when the valve rotor
20 50 is rotated. The conical shape of these washers 70 forces the o-rings
21 68 to attempt to lift the washers, thus stopping them from rolling over
22 the washers. This lengthens the o-ring life and makes a better seal.

23 Figs. 7 and 15 show the valve 40 in the calibration gas (CG)
24 position with rotor 50 rotated so that the opening 64a on the rotor's
25 bottom side 50c is aligned with the aperture 62. As depicted best in
26 Fig. 7, calibration gas proceeds along a flow path flowing through the
27 passageway 22a and aperture 62 into the opening 64a and then
28 through the gas conduit 64 and out the opening 64b into the
29 passageway 23 past the cell 30. As shown in Fig. 8, with the valve 40 in

1 the sample gas (SG) position, the rotor 50 has been rotated to align the
2 opening 64a with the aperture 61. Sample gas proceeds along a flow
3 path as follows: First, the sample gas flows along the passageway 22b
4 and out the block 18 and through the scrubber 9 and filter 82 into the
5 passageway 22b'. The sample gas next passes through the aperture 61
6 and into the opening 64a at the end of the gas conduit 64 and out the
7 opening 64b and into the passageway 23 leading to the cell 30. The
8 opening 64a is only aligned with one of the aperture 61 or 62 at a time.
9 When the valve 40 is in the OFF position, the rotor 50 has been moved
10 so that the opening 64a is displaced away from both the apertures 61
11 and 62 and the rotor's bottom side 50c covers both these apertures,
12 preventing any flow of gas past the detection cell 30.

13 As best depicted in Figs. 2 and 9, upon flowing past the detection
14 cell 30, the gas (either the calibration gas or sample gas) proceeds
15 along the following common flow path: First it flows along the
16 passageway 22c out the port P1 and into the inlet 11b of the flow
17 meter 11. It then flows through the channel 13 and out the flow
18 meter's outlet 11c into the port P2. The gas then flows through the
19 passageway 22c' out the gas outlet 7.

20 As illustrated in Figs. 2 and 16, upon entering the sample gas
21 inlet 6, the sample gas flows through a sample gas orifice 84 in the
22 block 18 at the entry end 86 of the passageway 22b. As the sample gas
23 flows through the sample gas orifice 84, a portion is diverted to flow
24 through the passageway 22d which has a bypass orifice 88 therein
25 located near a junction between the passageways 22d and 22d'. The
26 passageway 22d' extends between the bypass orifice 88 and the
27 passageway 22c', merging with the passageway 22c' at an intersection
28 92. Thus, a portion of the sample gas is diverted to the gas outlet 7 via
29 the bypass orifice 88 and passageways 22d' and 22c'. Approximately

1 from 5% to 10% volume percent of the sample gas is diverted to the gas
2 outlet 7.

3 An important feature of this invention is the use of both the
4 sample gas orifice 84 and the bypass orifice 88 to avoid the use of
5 pressure regulators. The sample gas orifice 84 and bypass orifice 88
6 each have substantially the same length of about 1/4 inch. The
7 diameter of the bypass orifice 88 is greater than that of the sample gas
8 orifice 84, preferably so that the area of the bypass orifice is at least 2
9 times greater than the area of the sample gas orifice 84.
10 Consequently, the area of the bypass orifice 88 is from about twice to
11 about four times greater than the area of the sample gas orifice. In a
12 preferred embodiment, the area of the sample gas orifice 84 is from
13 0.00001 to 0.0001 square inch, and the area of the bypass orifice 88 is
14 from 0.0001 to 0.0005 square inch. Typically, the area of these orifices
15 84 and 88 is circular, with the diameter of the sample gas orifice 84
16 being from 0.004 to 0.012 inch and with the diameter of the bypass
17 orifice being from 0.012 to 0.022 inch. With the valve 40 in the sample
18 gas position, from about 90 to 95 volume percent of the sample gas
19 flows past the detection cell 30.

20 During normal operation, gas flow is controlled by the sample gas
21 orifice 84. A feature of the orifices is that above a critical pressure, for
22 example 10 psig (pounds per square inch gage), the flow velocity is
23 limited to the speed of sound. Therefore, the mass flow is
24 proportional to the absolute inlet pressure. For example, this means
25 that, if the inlet pressure varies over a range of from 10 to 110psig,
26 the mass flow will vary over a rate of from about 0.5 to about 2.5
27 standard cubic feet per hour. The instrument 10 is not sensitive to
28 reading changes over this mass flow rate range. A pressure regulator is
29 therefore not required for normal operation.

When the valve is in the OFF position, sample gas may be introduced into the instrument 10 and this sample gas will flow through the bypass orifice 88 and be vented to the atmosphere through the gas outlet 7. For example, it is important to monitor continually a methane gas well where sample gas is always flowing into the instrument 10. Consequently, when the valve 40 is moved to either the calibration gas (CG) position or the sample gas (SG) position, there will not be a high level of pressure within the scrubber 9. Gas at high pressure within the scrubber 9 could damage the instrument 10 when the valve 40 is moved from the OFF position to the calibration gas (CG) position or sample gas (SG) position, since there is no longer any flow restriction. Because of the relationship between the sample gas orifice 84 and the bypass orifice 88, a build up of pressure within the scrubber 9 is avoided. Consequently, when the valve 40 is in the OFF position or calibration gas (CG) position, (a) the scrubber 9 is not over-pressurized, and (b) upon movement of the valve 40 into the sample gas (SG) position, there is no sudden high flow of gas pass the cell 30. During normal operation, the pressure in the scrubber 9 is very low since it is downstream of the sample gas orifice 84. There are no significant flow restrictions before the gas outlet 7, so the bypass orifice 88 does not allow much sample gas to flow through it in normal operation.

In operation and after calibration, the valve 40 is manually turned to the sample gas (SG) position to allow sample gas to flow into the instrument 10 under the control of the sample gas orifice 84. Because there is a differential in pressure of the instrument 10 (the instrument is at atmospheric pressure) and an elevated pressure of the sample gas, the sample gas flows into the instrument. Fig. 12 shows the relationship between inlet pressure and the downstream pressure in

1 the scrubber 9. At a low differential in pressure, the flow through the
2 sample gas orifice 84 is proportionate to this differential in pressure
3 and inversely proportional to the area. At higher differential
4 pressures, the flow rate gets faster and keeps increasing until the
5 velocity reaches the speed of sound. At this speed, gas velocity cannot
6 increase. However, increase in the upstream pressure of the sample
7 gas, proportionately increases the gas density, and therefore the mass
8 flow through the sample gas orifice 84 increases in direct proportion to
9 the absolute inlet pressure. The changes in downstream pressure,
10 however, have no significant impact on gas flow rate. A typical sample
11 gas orifice 84 is sized so that at an inlet pressure of about 60 psig, a
12 flow rate of about 4 standard cubic feet per hour of sample gas flows
13 through the instrument 10.

14 15 SCOPE OF THE INVENTION 16

17 The above presents a description of the best mode contemplated
18 of carrying out the present invention, and of the manner and process
19 of making and using it, in such full, clear, concise, and exact terms as
20 to enable any person skilled in the art to which it pertains to make and
21 use this invention. This invention is, however, susceptible to
22 modifications and alternate constructions from that discussed above
23 which are fully equivalent. Consequently, it is not the intention to
24 limit this invention to the particular embodiment disclosed. On the
25 contrary, the intention is to cover all modifications and alternate
26 constructions coming within the spirit and scope of the invention as
27 generally expressed by the following claims, which particularly point
28 out and distinctly claim the subject matter of the invention: